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Review

Changing Conditions: Global Warming-Related Hazards and Vulnerable Rural Populations in Mediterranean Europe

Sandra Graus [1], Tiago Miguel Ferreira [2,*], Graça Vasconcelos [1] and Javier Ortega [3]

[1] Institute for Sustainability and Innovation in Structural Engineering (ISISE), Department of Civil Engineering, University of Minho, 4800-058 Guimarães, Portugal; id10185@alunos.uminho.pt (S.G.); graca@civil.uminho.pt (G.V.)
[2] College of Arts, Technology and Environment (CATE), School of Engineering, University of the West of England (UWE Bristol), Bristol BS16 1QY, UK
[3] Institute for Physical and Information Technologies (ITEFI) Leonardo Torres Quevedo, Spanish National Research Council (CSIC), 28006 Madrid, Spain; javier.ortega@csic.es
* Correspondence: tiago.ferreira@uwe.ac.uk

Abstract: Human-induced climate change has profound effects on extreme events, particularly those linked to global warming, such as heatwaves, droughts, and wildfires. These events disrupt ecosystems, emphasizing the imperative to understand the interactions among them to gauge the risks faced by vulnerable communities. Vulnerability levels vary primarily based on a community's resources. Rural areas, especially in the Mediterranean region of Europe, are experiencing acute depopulation, creating a complex situation affecting various aspects of society, from economic declines to cultural heritage loss. Population decline in rural regions weakens resources, leading to the abandonment of built environments, fostering desertification, and elevating the risk of wildfires. Communities undergoing this deterioration process become exceptionally vulnerable, especially when dealing with and recovering from extreme natural phenomena. This review offers insights into the dynamics of these hazards and the predominant challenges in rural areas. By focusing on a topic that has received limited attention, the aim is to inform future research initiatives, ultimately improving risk assessment and mitigation strategies for these vulnerable communities.

Keywords: multi-hazard; change conditions; heatwaves; droughts; wildfires; vulnerability; rural depopulation

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1. Introduction

It is widely acknowledged that human-induced climate change has evolved into a significant global risk beyond natural climate variability. The past six years stand out as the warmest on record since 1880 [1–3]. Particularly notable are the drastic changes seen since 1950 in the Northern Hemisphere, marked by a temperature increase between of 1 °C and 4.5 °C in certain regions. These changes are intensifying the frequency and duration of extreme events, disturbing the environment and the lives of residents in vulnerable areas [4,5]. The risk in zones exposed to different and potentially interconnected natural hazards, such as prolonged droughts, intensified storms, landslides, higher wind speeds, wildfires, and extreme temperatures, among other events, during a specific period—a phenomenon known as a 'multi-hazard' [6–9]—underscores the urgent need for effective strategies to address the complex hazard landscape. Authors agree that traditional single-hazard approaches to risk assessment are no longer sufficient for understanding the real risks communities face [9,10] and therefore suggest transitioning from single to multi-hazard scenarios, despite the additional challenges this entails, such as the diverse characteristics of hazards, the vulnerability to distinct processes, and the resulting level of risk [9].

Recognized as a primary climate change hotspot [11], the Mediterranean region in Europe is notably sensitive to climate variations, with a land surface temperature already 1.5 °C above the pre-industrial level. In this area, a hotter and drier climate means a considerably higher risk of intense heatwave episodes, longer drought seasons, and severe wildfires, which can result in the irreparable loss of ecosystems and have acute consequences in various fields, including food production and security, human health and wellbeing, cultural heritage, and the deterioration of entire societies and economies [3,12]. Hazards can magnify social challenges in both urban and rural areas of the Mediterranean region, but they are particularly noticeable in rural areas. Cities are typically much more resilient to these phenomena than smaller, remote, and isolated communities, which often present a highly susceptible and intricate interaction between diverse dimensions of society (such as economic, institutional, social, cultural, etc.), undermining their resilience to hazards [13–15].

In the realm of rural landscapes, the increasing number of villages abandoned by their original inhabitants [16] are in a disadvantageous position compared to urban counterparts due to the repercussions of population decline [17]. These effects extend to economic stagnation and the weakening of community, social, and cultural resources [18]. Furthermore, the gradual deterioration of traditional built environments can evolve into the total abandonment of rural settlements [19], negatively impacting the natural environment and agricultural landscape [20]. Beyond the social drawbacks of rural depopulation, there is a critical consideration: when a rural community faces abandonment, unmanaged recolonization by shrubs and forests can occur, covering old agricultural land and heightening the risk of fires due to increased biomass [21,22]. As a result of the exposure of rural villages to these profound changes, communities develop different levels of vulnerability, which ultimately worsen pre-existing inequalities [23], severely disrupt their ways of life, and lead to the loss of security for the remaining inhabitants [24]. These conditions can potentially result in significant implications, involving the loss of livelihoods, loss of heritage, and the displacement of populations in harmful situations [25].

In the given context, this paper provides a comprehensive study of three closely intertwined topics: The impacts of climate change in the Mediterranean region are explored in Section 3, focusing on hazards such as droughts, heatwaves, and wildfires. By exploring these hazards within a multi-hazard framework, the paper highlights the interconnectedness of environmental challenges in the region in Section 4. Furthermore, the examination of rural communities experiencing depopulation in Section 5 adds depth to the analysis by considering the socio-economic factors exacerbating vulnerability. This holistic approach enables an understanding of the complex interactions between climate change, hazards, and rural community dynamics, discussed in Section 6, highlighting how depopulation can further exacerbate vulnerability to increased environmental challenges. In this discussion context, rural areas are understood as thinly populated areas located far from urban boundaries and encompassing a diverse range of landscapes and communities, with villages serving as one type of settlement within this classification [26,27].

2. Methods

In this study, a narrative methodological approach was employed to conduct the literature review. Unlike a systematic approach that follows a structured and predefined protocol, the narrative approach is based on the interpretation and synthesis of findings in a more holistic manner, allowing the researcher to explore a wide range of sources and perspectives, identify emerging themes, and provide a contextualized interpretation of the reviewed literature. This approach offers the advantage of capturing the complexity and diversity of ideas and theories present in the literature, allowing for deeper reflection and a richer understanding of the topics under study. Additionally, by offering a contextualized interpretation of the reviewed literature, insights and new directions for future research can be generated.

2.1. Search Strategy

A comprehensive search of relevant literature was conducted using electronic databases and online resources, including ScienceDirect, Google Scholar, ResearchGate, PubMed, Web of Science, and Scopus. These databases were chosen for their extensive coverage of scientific literature across various disciplines. Search terms and keywords were selected based on the specific themes of the literature review, including "high-temperature hazards", "wildfires", "droughts", "heatwaves", "multi-hazard", "vulnerable communities", "rural communities", "social vulnerability", and related terms.

In addition to academic literature, official data and reports from worldwide organizations such as the World Meteorological Organization (WMO) and the United Nations (UN) were consulted to establish definitions and provide context for high-temperature hazards. Online newspaper archives were also reviewed to identify previous occurrences of high-temperature-related hazards. Medical literature was searched to investigate the impacts of high-temperature hazards on vulnerable populations, focusing on studies examining the health effects of heat waves. Official systems such as the European Forest Fire Information System (EFFIS), Universal Thermal Climate Index (UTC index), and the European Drought Observatory (EDO) were consulted to gather relevant indicators and data on wildfires, droughts, and heatwaves.

2.2. Inclusion and Exclusion Criteria

The inclusion criteria for selecting literature about hazards related to high temperatures included studies published in peer-reviewed journals, official reports, and reputable online sources. Priority was given to recent publications (within the last ten years) to ensure the relevance and currency of information.

For the multi-hazard definition and classes, the inclusion criteria focused on scientific papers published within the last ten years to track the term's evolution and classifications. Given the relatively recent emergence of the multi-hazard concept, a broad search approach was employed to capture diverse perspectives and developments in the field.

Studies focusing on depopulation trends and the vulnerability of rural communities were included if they provided insights into the characteristics of rural areas that make them vulnerable to different hazards. A timeframe of the past 20 years was chosen to capture historical trends and changes in rural populations and to understand the evolving challenges faced by these communities.

2.3. Selection Process

The initial screening of literature involved reviewing titles and abstracts to identify potentially relevant studies based on the inclusion criteria outlined above. Full-text articles were then retrieved and assessed for eligibility. Discrepancies or uncertainties regarding the inclusion of specific studies were resolved through discussion among the research team members.

2.4. Data Extraction and Synthesis

Data from the included studies were extracted and synthesized to identify key findings, themes, and patterns related to the three main themes of the literature review. Information relevant to hazards related to high temperatures, multi-hazard interactions, and the vulnerability of rural communities was synthesized to provide a comprehensive overview of the literature. Qualitative and quantitative data were analyzed and organized in the following sections.

3. Hazards Related to High Temperatures in the Mediterranean Region

The exacerbation of hazards in Mediterranean ecosystems due to global warming presents immediate challenges. To start with, elevated temperatures can cause extensive water evaporation from all wet surfaces and soils. Along with decreasing rainfall, evaporation leads to shrinking water resources on land, reduced river flow, and significantly more prolonged and severe drought spells, especially in summer [3]. In this season, heatwaves increase in frequency and intensity [28–30], circumstances that can worsen drought, exacerbating hot and dry conditions that are strongly associated with large fires in rural areas [31–33].

This section digs into the complexities of three related hazards whose frequency and severity have been magnified by climate-change-related weather variability: heatwaves, droughts, and wildfires. Each threat, driven by the growing climate crisis, triggers a unique set of consequences that impact the environment, affecting everything from human health to biodiversity.

3.1. Heatwaves

Heatwaves, as defined by the World Meteorological Organization (WMO), are characterized by a period of more than two consecutive days during the hot period of the year where thermal conditions (maximum and minimum temperatures) are unusually high for a location [34,35]. These extreme events are mainly characterized by high temperatures and humidity levels, which, combined, can have harmful effects on the population's health as a consequence of heat-related stress [36]. High temperatures combined with low humidity, on the other hand, may exacerbate droughts. While each heatwave is different and has individual climate dynamics behind it, the probability of these events is a direct consequence of the warming planet [37]. Globally, the highest temperatures in the last 20 years were reached during the European summer, highlighting summer 2022 as the warmest summer on record so far [38].

Heatwaves are among the most dangerous natural hazards. However, although nowadays their impact is noticeably correlated with increased mortality due to their increased frequency and intensity, heatwaves rarely receive adequate attention from society in comparison with other sudden hazards, as their effects are not always immediately evident, requiring prolonged periods to develop [39]. Frequent heatwaves and the absence of precipitation can potentially lead to water scarcity, increase plant stress, reduce plant growth, and affect the food chain [40]. Heatwaves can influence drought periods, which may cause critical material damage, business and essential service disruption, and transport issues for the industry [36,41]. These extreme conditions can increase thermal discomfort and the need for cooling in buildings, which in turn not only increases economic costs but also the emissions from carbon-based energy sources [40]. In addition, thermal and chemical stress increases in many materials, such as marble, stone, and masonry, used in historic structures [3,42].

Concerning population, exposure to hot days and nights can affect human health and wellbeing in various ways, from psychological and physical discomfort to severe health impacts such as heat exhaustion, dehydration, heatstroke, and ultimately death [36]. The body's physiological reaction to external conditions is measured by the Universal Thermal Climate Index (UTCI), which is divided into ten stress categories ranging from extreme heat stress (above 46 °C/115 °F) to extreme cold stress (below −40 °C/°F) [43]. The UTCI considers not just the ambient temperature but also other variables like humidity, wind, and radiation. It is applicable in investigating impacts on health, energy consumption, or even human migration due to extreme climate [44]. According to the European State of the Climate report in 2021, Southern Spain reached an 'extreme' heat stress level linked to relatively intense heat waves [45].

The mortality associated with a heatwave episode depends not only on the location's bioclimate but also on the strategies used to prevent and manage the event. Studies have shown that death counts increase in conditions of moderate and strong stress when UTCI is above 32 °C [44]. This significant rise in mortality rates tends to occur particularly in those with cardiovascular and respiratory diseases [46–48]. Globally, in 2019, approximately ninety-three thousand deaths from heat-related cardiovascular diseases were recorded, an increase six times greater than that observed in 1990 [49].

In contexts of excessive heat, mortality rates tend to rise among vulnerable groups of people such as children and pregnant women, the elderly, the chronically ill, socially isolated individuals, and other fragile population groups [3,50–52]. Extreme heat additionally diminishes individuals' work capacity, leading to decreased productivity and, consequently, lower economic outcomes. Future projections indicate that without the implementation of further adaptation actions by 2060, impacts in Europe could rise by nearly five times compared to the historical period from 1981 to 2010. This suggests an intensified occurrence of more-pronounced consequences in regions where damages are already severe, such as the southern part of Europe [53].

Historically, notable episodes of severe and prolonged heat waves have occurred in Southern Europe, in some cases linked to other hazardous conditions such as droughts and wildfires. For example, the European heatwave of 2003, which hit Western Europe in early June 2003 causing around 70,000 excess deaths over four months [54], was Europe's most lethal heatwave of recent decades. France, Italy, Spain, and Portugal were particularly affected, with record temperatures of 47.3 degrees Celsius. Studies revealed that an excessive number of deaths was concentrated in elderly and isolated vulnerable people [55]. Another heatwave in 2007 caused more than 500 deaths in Hungary, while Italy suffered from severe wildfires. The phenomenon began by affecting Italy and Turkey and expanded into Greece and the rest of the Balkans. The costs of the heat wave were estimated at two billion euros [56]. Heatwaves in 2017 affected the south of the European continent from June till mid-August, with Spain marking its highest-ever recorded temperature of 47.3 °C in the small town of Montoro near Cordoba. Daytime temperatures remained above 40 degrees for a whole week. The ongoing drought also sparked wildfires, particularly in Portugal. High energy and water consumption during prolonged heat waves also strain supplies [57]. The European heatwave in 2018 was preceded by an intense drought across Europe, with rising temperatures in the second half of July and early August reducing the Danube River to a historic low. In parallel, wildfires raged across Spain and Portugal [58]. In 2021, heatwaves mainly affected Greece with temperatures that reached 45 °C, and over 2300 excess deaths were documented between late July and mid-August (compared to the previous five years and excluding coronavirus mortality) [59]. The same year, Italy and Spain were also affected by intense heat, triggering wildfires. And from June to August 2022, heatwaves caused over 1700 deaths in Spain and Portugal alone [49], with a major percentage of these deaths being people over 65 [60]. The highest temperature recorded was 47.0 °C in Pinhão, Northeastern Portugal, aggravating destructive wildfires, forcing the evacuation of people, and emphasizing an unprecedented drought [61,62]. Finally, in August 2023, Southern Europe experienced widespread heatwaves from Portugal to Italy and the Maghreb, accompanied by persistent dry conditions. This led to a significant increase in wildfires, particularly in July and August. The high temperatures caused extensive heat stress on the people, with some regions experiencing up to 60 days of "very strong" heat stress, reaching temperatures between 38 and 46 °C [63].

3.2. Droughts

As another hazard derived from global warming, droughts have become more frequent and intense, especially in Mediterranean Europe [3]. Drought is a natural phenomenon related to meteorological conditions, defined as a deficiency of precipitation over an extended period (usually a season or more), resulting in a water shortage [64]. The impacts of drought can be made worse by the demands that humans place on water supplies. Drought should not be confused with aridity, which is a long-term average feature of a dry climate. It also differs from water scarcity, which, by definition, is an imbalance between water availability and demand [65]. Droughts result from a deficit of normal rainfall conditions during a certain period. If the timeframe expands, the complexity and severity of the impacts also grow in scale. Thus, according to the duration, three main types of droughts can be considered: meteorological, agricultural, and hydrological [66,67].

Initially, a meteorological drought is related to the degree of dryness compared to an average amount and the duration of the dry period in a specific region and atmospheric conditions [66]. Over time, in these conditions, when the impact quickly extends to the soil, aggravating the reduction in soil moisture content and causing harsh conditions for plants to grow, an agricultural drought can develop. Finally, a hydrological drought happens when the water levels in riverbeds decrease, causing a drop in volumes stored in reservoirs and infiltrations to recharge groundwater [67]. When drought impacts reach the hydrological level, reducing streamflow, hydroelectric power production capacity can be significantly affected. In those situations, if the rainfall deficit continues, it can lead to water scarcity for human activities, resulting in severe socio-economic impacts. This level is also known as socioeconomic drought [66–68]. Since global temperatures continue to rise, a more recent approach focuses on ecological drought, defined as a prolonged and widespread deficit in naturally available water supplies—including changes in natural and managed hydrology—that create multiple stresses across ecosystems [66].

Based on the analysis of the Combined Drought Indicator (CDI), the European Drought Observatory (EDO) has identified areas with the potential to suffer agricultural drought, areas where the vegetation is already affected by drought conditions, and areas recovering after a drought episode. CDI is based on indicators that evaluate different components of the hydrological cycle, such as precipitation, soil moisture, reservoir levels, river flow, and groundwater levels, besides specific impacts associated with a particular type of drought. In recent years, especially during summer, a significant extension of the European continent has struggled with problematic drought conditions, creating soil moisture deficit and vegetation stress, apparent symptoms of an agricultural drought [69]. Since 2011, the EDO has reported about 21 severe drought occurrences in Southern Europe. The year 2022 was particularly acute, with severe impacts reported in water supply, ecosystems, agriculture, energy, and public safety, which, combined, resulted in economic losses of around EUR 9 billion [70].

Prolonged or recurring periods of drought have significant impacts on agriculture, with consequences including crop failures, higher incidence of plant disease, or even total harvest failure, ultimately leading to a food crisis. In the occurrence of a prolonged drought, the ground and flora can be so severely damaged that the land becomes desert [3,71]. Soil damage affects not only the production field but also the built environment. Some studies affirm that one of the consequences of drought is the risk of subsidence (clay-shrinkage-induced subsidence). This means that in some European regions where buildings are constructed on top of swelling clay, the ground may shrink during a drought, leading to building subsidence and causing cracks and tilting [72].

To avoid the waste of water resources, some countries have reduced the use of hydroelectric energy, increasing the consumption of electricity produced through fossil fuels [68]. Despite that, a shift to fossil fuel-based energy can contribute to environmental issues such as air pollution and greenhouse gas emissions, worsening climate change concerns. Additionally, in rural areas of South Africa, management strategies during times of drought reduce the supply of water only for domestic use in rural areas, excluding farmers' activities [73]. In many Mediterranean countries, the balance between demand and water availability has reached a critical level. It is expected that in 2025, half of the region will use more water than the naturally regenerated amount [74]. These events could cause water shortages in cities and rural areas with small supply systems [67], increasing the risk of water scarcity for human and animal consumption, including activities such as the mitigation of wildfires [75].

3.3. Wildfires

The incidence of devastating summertime wildfires is on the rise in Europe, causing economic and ecological losses and sometimes human fatalities. When the rainy and mild winters that increase the fuel load available are followed by warm and dry summers that increase the fire risk, the Mediterranean region becomes especially prone to severe fire events [76]. It is essential to note that while statistics on the causes of wildfires are far from complete, approximately 95% of wildfires in Europe are alleged to result from human actions and activities, whether through negligence or deliberate acts such as arson [77,78]. Fires indirectly caused by humans without the use of fire (by accident) are relatively rare and typically associated with factors such as electrical line failures, sparks from train brakes, or emissions from engines and machinery. On the other hand, fires unintentionally ignited by people using fire or glowing objects (by negligence) are more prevalent in occurrence. Negligent fires are mainly linked to agricultural burning for biomass removal and vegetation management for forestry and pasture purposes [79,80]. As younger generations move away from their territories and the average age of farmers increases, traditional fire management techniques are disappearing, and this could lead to a rise in fires caused by human error or a lack of understanding of fire dynamics and management techniques [81].

Wildfires need the right climatic conditions and a source of ignition, as well as fuel to burn and expand. All vegetative biomass is potentially fuel for wildfires, and this fuel can be distributed both vertically and horizontally, a concept commonly referred to as fuel continuity. Continuous fuels are necessary for a fire to spread across the landscape (horizontally) or from the forest floor into the canopy (vertically). Fuel continuity is such a fundamental concept in fire studies for understanding why ignitions (natural or human-caused) are persistent and can spread from one fuel source to another [82]. Where a sufficient amount of fuel exists, low fuel moisture availability plays the most critical role in propagating large fires, with severe impacts documented for areas of Mediterranean climate [83]. Furthermore, wildfires can arise from a combination of natural factors such as weather and climate. For the fire–weather relation, four conditions for large wildfires can be named: (i) heat-driven wildfires driven by temperature and the dryness of fuels, associated with calm winds and sustained hot and dry conditions; (ii) heatwave wildfires driven by extremely high temperatures, which cause the rapid dehydration of fine fuels and litter, while the moisture content of heavy fuels is not low; (iii) seasonal drought wildfires associated with extended drought periods, leading to dry, heavy fuels; and (iv) wind-driven wildfires occurring on days with sudden warm conditions, such as low relative humidity and very strong winds during the day of ignition [84].

Given the inherently arbitrary nature of fire ignition, early warning systems for fires worldwide primarily focus on assessing fire danger, providing valuable information about the environmental conditions that increase the likelihood of fires occurring [85]. In the context of the European Forest Fire Information System (EFFIS), the Fire Weather Index (FWI) is used for producing fire risk maps to understand the flammability of specific areas and to evaluate the potential danger [12]. This index, used for assessment, considers two main components: fire danger and the vulnerability of people, ecological systems, and economic values in susceptible areas. EFFIS identifies regions with elevated wildfire risks, including Northern Portugal, Northeastern Spain, Southern Italy, and Northern and Southern Greece, particularly in densely populated urban areas [86,87]. Simultaneously, the depopulation of rural areas and expansion of urban zones has led to the creation of interfaces between residential and unoccupied land worldwide, especially in Europe [88]. The rural–urban interface, also referred to as the wildland–urban interface, exhibits several challenges, especially during wildfire emergencies. Given that these areas concentrate significant human life and property, they can be susceptible to potential devastation by wildfires across large geographic regions [88,89].

Wildfires in Europe, with an annual cost of approximately EUR 3 billion since 2000 [90], can result in land degradation, desertification, biodiversity loss, livelihood disturbances, the movement of communities, and the destruction of historical and cultural features, artifacts, places, and buildings [91]. Southern European countries present the most significant number of occurrences of fires and amounts of burned land [12]. In 2023 alone, the total burned area reached approximately 330,000 hectares of forest, practically twice the average of preceding years [86]. Additionally, wildfires increase air pollution levels and can also harm people's mental health. Beyond asset loss, wildfires accelerate soil erosion, magnifying potential risks during intense rainfall occurrences [92] and setting the environment up for subsequent hazards.

In summary, hazards related to high temperatures in the Mediterranean region, exacerbated by global warming, significantly impact human health, the environment, and the economy, underscoring the urgent need for mitigation and adaptation actions. In confronting these hazards, rural communities encounter significant challenges stemming from their social vulnerability, which is influenced by intrinsic factors such as limited access to resources, remoteness, social isolation, the susceptibility of the population, and other characteristics elucidated in Sections 5 and 6.

4. Multi-Hazard Interactions: Change Conditions

In the face of evolving climate patterns and environmental changes, communities are increasingly exposed to the complex interaction of different and multiple hazards. Multi-hazard events include more than one hazardous activity within a specific geographic area and time period [7,8]. In these scenarios, risk components such as exposure and vulnerability may experience alterations, causing a profound impact on communities, infrastructure, and heritage in urban or rural areas, resulting in notably higher economic losses compared to single-hazard events [93,94].

The absence of a global standard for classifying multi-hazard interrelations [94,95] emphasizes the persistent challenges in this domain. However, it also provides an opportunity for comparison among diverse authors. Zscheischler et al. [96] suggest the classification of multi-hazard interactions into four themes. These encompass 'preconditioned' scenarios, where weather preconditions exacerbate hazard impacts; 'multivariate' instances, where impacts result from the occurrence of multiple hazards; 'temporarily compounding' situations, where impacts stem from a sequence of hazards over time; and 'spatially compounding' events, where hazards in interrelated locations collectively contribute to cumulative impact [96].

Along the same line, Ferreira and Santos [6] offer a valuable framework by categorizing multi-hazard interactions into five distinct types. These include 'independent' hazards, coinciding without inherent connections; 'triggering' events, where one hazard leads to another; 'change conditions', involving alterations in environmental conditions that increase the probability of a new hazard; 'compound' events, occurring simultaneously to create new or intensified risks; and 'mutual exclusion', where specific hazards may reduce the impact of a former one [6]. The diversity in these proposed classifications emphasizes the complexity of understanding and categorizing multi-hazard interactions but also highlights the need to establish standardization, regardless of differences in the hazard's nature, duration, magnitude, and other factors.

Given the nature of this research, which aims to explore the relationships between threats, the primary focus of the study centers on a specific type of multi-hazard interaction known as 'change conditions' [6,8], alternatively recognized as 'increasing probability' [7], 'preconditioned' [96] or 'amplification interrelationship' [97] events. In general, this category involves variations in environmental parameters due to the impact of a first hazard. When the environment is modified, it can influence the likelihood and magnitude of a secondary hazard without directly triggering it [7,93,97]. Numerous instances have been observed involving the occurrence of this type of multi-hazard, with wildfires serving as a prominent example. In steep terrains, wildfires can increase the susceptibility to landslides (triggered by rainfall or earthquakes, for example) since they detrimentally impact vegetation, diminishing the slope shear strength [7]. Conversely, hazards associated with elevated temperatures, such as heat waves or droughts, can amplify the likelihood of wildfires by promoting hot and arid conditions in the environment [97–99]. These conditions are expected to increase in the future, leading to a rise in multi-hazard events and unequal impacts [100,101], particularly in regions that accumulate high exposure with significant levels of vulnerability due to a lack of resources. Hazards such as heatwaves, drought, and wildfires have the potential to cause extensive damage to assets, influencing associated biodiversity, ecological conditions, and community resources [31,32,102–104].

During drought conditions, pastures and trees can dry, increasing the amount of highly flammable vegetation (fuel) [75]. Decades ago, the amount of fuel was drastically reduced by agricultural activities, wood gathering, and overgrazing of goats and sheep, maintaining a fuel-limited fire regime. However, land-use changes, socioeconomic transformations, rural depopulation, consequent land abandonment, and, in some cases, reforestation projects have caused an increase in the volume of available fuels and their distribution [82,104]. Consequently, fire regimes switch from fuel-limited to the present drought-driven fire regime [31,33]. Based on this context, even contemporary initiatives have surfaced, proposing conservation strategies such as trophic rewilding [105,106]. This approach looks to mitigate the risk of wildfires and their environmental impacts by reintroducing species like large herbivores and predators, which can reduce fuel loads in fire-prone locations.

Whether occurring as a single or multi-hazard event, drought has been identified as the leading cause of mortality, contributing to 36% of the 33 million fatalities resulting from the 16,535 disasters recorded worldwide between 1900 and 2023 [94]. Meteorological droughts, characterized by their extended duration, can induce considerable temperature elevations as soil moisture decreases [96]. The connection between droughts and heatwaves lies in their shared influence on temperature rise and precipitation decline, indicating potential similarities in their impacts. However, the distinction emerges from the fact that drought disasters consistently bring high temperatures, whereas heatwaves, despite their short duration, can occur without triggering such intense disasters on their own [95,100,107]. Nevertheless, it is crucial to recognize that even short heatwaves can have severe consequences on population, particularly on public health, as in 2022, when Europe witnessed 61,672 heat-related deaths [52]. In addition, drought episodes are also recognized as primary drivers for increases in the occurrence of wildfires [32,101]. Even though drought conditions may develop gradually over an extended period, they often lack distinct starting and ending points. But notably, during the early stages of the fire season, between late spring and early summer, severe droughts inevitably induce heightened vegetation stress, intensifying the flammability of dried fuels [76]. Additional extreme conditions, including heatwaves [7] combined with intense wind [84], create favorable environmental conditions for the dangerous spread of wildfires. Consequently, the carbon dioxide emissions from wildfires can adversely affect the cardiovascular and respiratory systems of the population, intensifying the impact of heat stress [85].

According to the International Disaster Database (EM-DAT) https://www.emdat.be/ (accessed on 14 January 2024), Southern Europe experienced 138 cases of high-temperature-related hazards between 1966 and 2023, including 75 wildfires, 42 heat waves, and 21 droughts, which caused approximately 80,000 deaths. Spain, Greece, Portugal, and Italy showed the highest incidence of wildfires. About 30% of recorded wildfires include information about weather conditions during their occurrence, mainly associated with high temperatures, heat waves, and droughts. However, it is crucial to acknowledge that not all events are thoroughly detailed, primarily due to a lack of data. This scenario highlights the need for a systematic understanding of the interactions among hazards in 'change conditions' for a clear, consistent, and optimized multi-hazard risk assessment.

Simultaneously, it is imperative to recognize the potential for complex interactions among related hazards, particularly considering the influence of climate change, which has intensified the frequency of these events in urban and rural areas. As has been mentioned, the assessment of multi-hazard risks poses difficulties due to the diverse temporal and spatial scales of hazardous events and the need for a better understanding of hazard interrelationships. Ahead of hazardous events, rural communities, in particular, encounter challenges in hazard mitigation and recovery due to limited capacity and resources. In contrast, urban areas are challenged due to their rapid urbanization and high population density, complicating emergency response and recovery efforts [13].

Research and policy efforts have increasingly focused on multi-hazard risk assessment and management. Frameworks and tools are being developed to account for the interactions and interdependencies among different hazards and vulnerabilities across diverse systems and communities [23,97,108,109]. In this sense, understanding multi-hazard scenarios is crucial for designing and implementing effective mitigation and resilience strategies. To address multi-hazard risks comprehensively, an integrated methodology is necessary, considering the interconnected nature of various hazards and their implications for all segments of society, prioritizing vulnerable communities.

5. Depopulation Trends in Mediterranean Rural Areas

Depopulation can be defined as a demographic and territorial phenomenon that reduces a territory's population or a population nucleus in a specific timeframe [110,111]. This systemic phenomenon affects demography and influences the community structure in its economic, social, environmental, political, and cultural dimensions. It is worth highlighting that depopulation, as a trend, can occur in different areas, including large cities and densely populated spaces; however, when it affects low-density areas such as villages, which are unbalanced in terms of age, gender, and qualifications and also lack access to basic services, it is especially threatening.

Commonly, depopulation is linked to the adverse values of two primary indicators: natural population change (the difference between birth and death rates over a specific period) and net migration (the disparity between emigrants and immigrants). In Europe, the Mediterranean region has faced a notable decline in the birth rate, which is insufficient to sustain population growth, coupled with a negative net migration rate. This led to the Mediterranean region recording the lowest natural population change value in 2014 [111]. The trend persisted, and between 2015 and 2020, the most significantly affected areas were in the northern and central regions of Greece, Southern Italy, including Sicily and Sardinia, Northwestern Spain, and Eastern Portugal. Concurrently, there was a noticeable concentration of the population in large urban areas and coastal regions [111–113].

Positive developments in health and socioeconomic progress have improved the population's life expectancy, increasing the aging tendency [114]. However, in depopulated areas, the deficit of births over deaths translates to a decline in the number of children. This ongoing decrease results in fewer young people and a proportional increase in the population at older ages, a phenomenon known as population aging [115]. Notably, in 2015, European regions with the highest percentages of elderly populations were identified in the rural Portuguese region of Pinhal Interior Sul (33.6%), the central Greek region of Evrytania (31.0%), and the northwestern Spanish region of Ourense (29.4%) [14]. Currently, the proportion of people over 65 years old exceeds 20% of the population in countries such as Spain (26.8%), Portugal (24.7%), Greece (24.2%), and Italy (23.3%) [113], particularly in remote rural regions where the oldest populations were still concentrated in 2019 [116]. These regions significantly coincide with those experiencing depopulation [111].

Migration also plays a crucial role in shaping the demographic profile of a population. Typically, migration can reduce the impact of population aging, given that many immigrants are generally young, seeking refuge from persecution or conflict, exploring employment prospects, and pursuing an improved quality of life [117]. However, it is essential to note that immigration is unlikely to fully offset depopulation and aging trends in the rural areas of Southern Europe. Immigrants often concentrate in larger cities where opportunities are more abundant, leaving rural areas more susceptible to the challenges of depopulation [111]. Depopulated rural areas not only experience a significant aging trend but also undergo masculinization, driven by the increasing volume of female emigration. This phenomenon exemplifies the gender disparities in opportunities that often define rural family structures, making the process of forming new families more difficult and causing men to remain single and without progeny [118,119].

Beyond demographic alterations and territorial imbalances, rural villages undergoing a depopulation process face various vulnerabilities due to a combination of factors.

Population decline significantly impacts economic growth by reducing the labor force, particularly the working-age population, a critical factor directly influencing economic productivity [114,120]. A deteriorating labor force may lead to a long-lasting shortage of skilled workers, posing challenges for many local businesses [121]. Depopulation exacerbates the gap between supply and demand for services or products in the local market. Fewer people need fewer products, and services become underutilized and poorly maintained. Services may become financially unsustainable and eventually withdrawn, contributing to a rise in unemployment [14,122,123] and leading to a 'desertification of services' [113].

In the agricultural sector, combined demographic and economic decline leads to a scarcity of farm labor and can be a trigger for the abandonment of agricultural land [17,19,124,125]. The presence of very small or semi-subsistence farms raises significant concerns, especially since, in most Mediterranean countries, less than 30% of farmers have additional sources of income to supplement earnings from agricultural activities. As income is a widely used indicator in analyzing poverty and social exclusion in rural areas, the lack of diversified income sources puts around 70% of small farmers at a specific risk [126]. Economic conditions can contribute to the stratification of social groups, creating a spectrum from high-income to low-income individuals and fostering social polarization between deserted rural areas and densely populated urban areas [127]. Affected regions also have restricted budgets and a reduced tax base, making them highly reliant on external funding sources. This situation puts pressure on government budgets to fund essential services [14,121]. This scenario is particularly evident in Southern European countries where austerity policies have reduced public and private rural service networks, including postal offices, banks, public transport, infrastructure, schools, medical facilities, and other public services [113,126]. This has diminished local governance capacity and delayed proactive economic policies for territorial development [111].

Insufficient access to social services plays a crucial role in rural development since social services fulfill people's daily needs and contribute to their wellbeing. For instance, the closure of essential services, such as schools, can trigger outward flows of families with young children in search of better educational facilities [127]. The absence of essential services, also known as services of general interest (SGIs) in Europe, further diminishes the attractiveness of shrinking regions. This erosion of local living conditions and quality of life makes these areas less appealing to new immigrants. Plus, it contributes to the exodus of current residents, intensifying the spiral of decline associated with falling fertility rates and the aging of the remaining population [111,121]. In an aging society, the growing number of elderly individuals with disabilities, with little or no support from relatives, results in an increasing demand for health services [114]. This situation is particularly challenging in rural areas where hospitals and other care facilities cease operations, and urban health infrastructure becomes inaccessible due to long distances.

Remoteness generates a significant challenge in rural areas, impacting connectivity and overall accessibility [126]. Defined by both physical distance and a lack of connection, an area is deemed remote if less than half of its residents can reach the center of a city with a population of at least 50,000 within 45 min [128]. For declining remote rural areas, extended travel times to urban centers hinder access to services of general interest (SGIs). The lack of accessibility, a crucial aspect of social and territorial cohesion, adversely affects the quality of life for individuals already at risk of social exclusion [113,126]. Additionally, rural areas are also often isolated from broader networks and typically far from centers of political authority. In terms of decision making and governance arrangements, remoteness diminishes the influence of local actors, making it challenging to initiate strategies or gather the necessary resources to address demographic and economic decline [111]. For its part, connectivity, including the quality and speed of internet access, plays a vital role. The absence of robust telecommunications infrastructure, associated with the digital illiteracy of the citizens, holds back population settlement and economic development. The presence of high-speed digital infrastructure, along with efforts to reduce the digital gap, enhances the capacity of rural areas to leverage their digital potential, mitigating the effects of low connectivity [129,130].

The increasing emigration of young people produces a gap between generations, separating individuals from friends and family, disrupting social cohesion within communities, and limiting the transmission of essential traditions, knowledge, and ancestral techniques. This can lead to the disappearance of traditional working contexts, contributing to undermining community interactions [24] and progressively generating collective changes at the core of social memory, influencing the identity and sense of belonging of the remaining population [131]. If the population fails to maintain a meaningful connection with their land, this can potentially lead to the abandonment of settlements, posing a significant threat to both tangible and intangible cultural heritage [122]. Although inhabitants of rural villages have strong bonds with the living environment and traditions [20], in critical situations of abandonment, the neglect of built heritage can arise, exacerbating the challenge [17,20]. Rather than being preserved, these architectural expressions are left in a state of deterioration, contributing to the erosion of local identity. This situation triggers a cycle where the population is unable to identify territorial elements, reducing their sense of belonging to the community [132]. Without proactive measures to safeguard valuable cultural heritage, there is an imminent risk of potential authenticity loss in vernacular buildings, which, in turn, could result in the subsequent loss of identity of settlements and rural landscapes [127,133,134]. Ultimately, the act of abandoning rural communities is closely associated with soil degradation and desertification [125]. Land desertification is tied to damage to local biodiversity and is correlated with the increased risk of wildfires due to the spontaneous development of uncontrolled nature on abandoned sites [135–137].

In consensus with several authors [138–140], it becomes evident that restricted access to various resources significantly influences the vulnerability of communities. Beyond social, economic, political, or technological inequalities, factors such as inequality in geographic location, community attributes, the fabric of the built environment, and levels of urbanization also play a fundamental role in shaping social vulnerability. Socially vulnerable communities and their built heritage can be at heightened risk in the face of pronounced emergency situations triggered by natural hazards. The pivotal element in addressing these challenges lies in the perception of the community members because awareness is essential to activate community resilience. It serves as a crucial factor in empowering the community to confront extreme conditions, raising adaptability, and enabling the renewal of the community organization [24].

6. Challenges of Vulnerable Rural Communities Facing Multiple Hazards

In the presented context, rural depopulation stands out as a critical issue with extensive consequences, notably amplifying the vulnerability of the affected communities to various hazards. Figure 1 summarizes the challenges that rural communities face when their population decreases and grows older. As was said before, these challenges are interconnected and vary due to a combination of demographic, economic, social, cultural, administrative, and environmental factors.

In the beginning, demographic decline and the aging population influences the labor force, reducing the capacity of these communities to distribute their limited resources to emergency preparedness. Lack of opportunities, adverse geographical features, and the absence of crucial infrastructure, such as roads, bridges, and emergency services, interfere with immediate and efficient responses to hazards. Moreover, disrupted social relationships and community support further weaken collective resilience, delaying the effective confrontation of environmental challenges. Every step influences the depopulation cycle until the imminent abandonment of the rural landscape and their built heritage occurs.

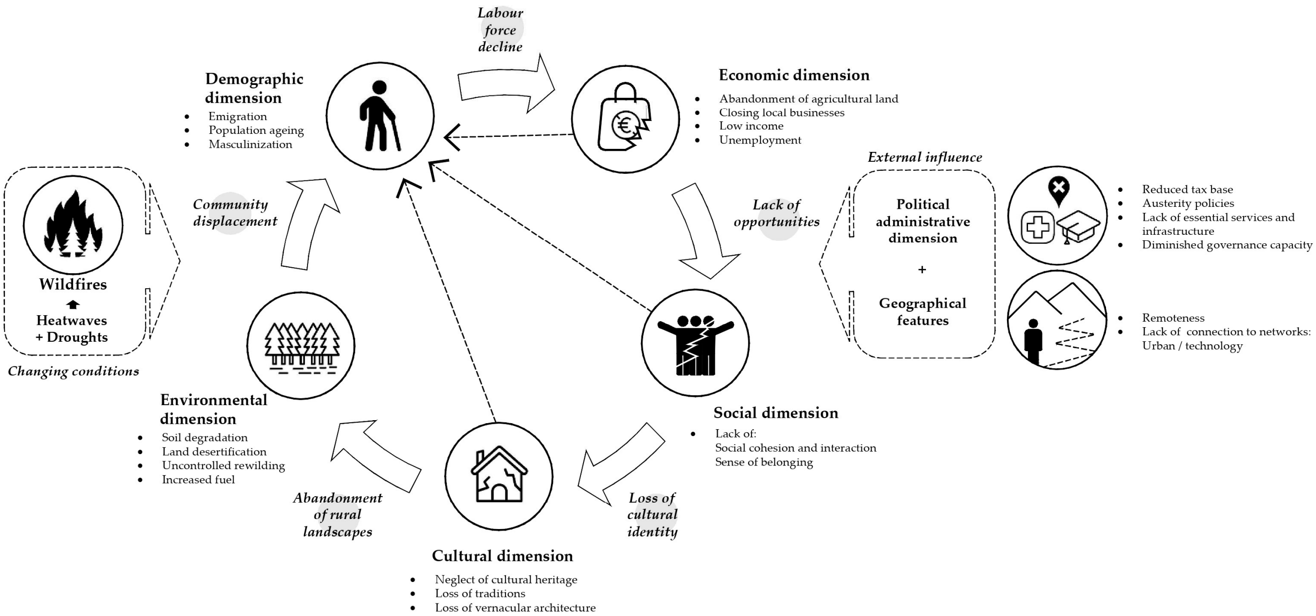

Figure 1. Graphic scheme of challenges in rural areas due to depopulation and multiple hazards.

In addition to this scenario, the impacts of heatwaves and droughts can apply immense stress to essential water resources and simultaneously create hot and dry environmental conditions conducive to the intensification of wildfires, resulting in the destruction of forests and vernacular buildings and potentially the loss of life. Ultimately, these circumstances may influence residents to abandon their homes in search of more sustainable living conditions, further diminishing the appeal of rural living and perpetuating the cycle of depopulation, creating a feedback loop. Breaking this cycle requires comprehensive strategies that address both vulnerability and hazard mitigation, with a particular focus on the community and its sustainable development.

Numerous studies [141–143] underscore the critical importance of developing effective strategies for resilience and adaptation. The initial step in this process involves the identification of all potential hazards in a given area, including their impacts and the elements at risk, to recognize the most vulnerable areas [139,144]. Various methods are employed to assess vulnerability to hazards in rural areas, with indicator-based approaches commonly used to simplify data collection and comparison, providing valuable insights [144]. For instance, Kappes et al. [93] focused their study on assessing physical and social vulnerability to multiple hazards in a municipality of the French Alps, utilizing an indicator-based methodology. This approach involved identifying relevant hazards such as debris flows, shallow landslides, and river flooding, adopting a multi-hazard perspective to support decision making and risk reduction efforts. Subsequently, vulnerability indicators were determined, and the resulting social vulnerability index map was combined with hazard maps to obtain social vulnerability exposure maps. This process facilitated the identification of hotspot areas, where the social fabric could amplify the consequences of potentially dangerous events. The research also highlights the qualitative nature of vulnerability measurements and the substantial amount of data required for their performance.

In contrast, Frigerio et al. [145] focused their study on assessing social vulnerability only to seismic hazards in Italy through a multidisciplinary framework that integrated physical (earthquake hazard) and human (social vulnerability) dimensions. Employing a GIS-based approach, they constructed and mapped social vulnerability indicators to identify areas with high levels of seismic hazard and social vulnerability, offering valuable information for risk mitigation strategies, emergency management, and territorial planning. The study emphasizes the importance of integrating social vulnerability studies into disaster risk reduction policies, particularly in regions prone to natural hazards like earthquakes. Similarly, Oliveira et al. [146] aimed to provide practical and operational tools for decision-making processes in wildfire management. They developed a comprehensive framework for assessing and mapping wildfire vulnerability in Mediterranean Europe, evaluating exposure, sensitivity, and coping capacity as the main components of vulnerability. The study integrated data on population density, fuel types, protected areas' location, road infrastructure, and surveillance activities to create composite indices. Additionally, the study stressed the significance of integrating feedback from end users and stakeholders to ensure the operational application of the vulnerability assessment framework.

In recent years, Chas-Amil et al. [147] studied vulnerability in the context of wildfires in Galicia, Spain, utilizing a hazard-of-place approach [140] to quantify differences in social vulnerability across municipalities. This involved creating a social vulnerability index (SoVI) from a set of variables such as socioeconomic status, social-dependent population, household unit characteristics, education, health services, and socio-cultural institutions. The study incorporated historical data on wildfire events to analyze and map the spatial coincidence of social vulnerability and wildfire risk, aiming to identify areas to improve preparedness and enhance social resilience to wildfires.

As has been seen, the reviewed studies underscore the intricate nature of vulnerability assessments and stress the significance of employing comprehensive strategies for resilience and adaptation to different hazards. Through the integration of multidisciplinary frameworks, indicator-based methodologies, and GIS-based approaches, researchers have proficiently identified and mapped vulnerabilities in diverse contexts. This not only contributes to effective decision-making processes but also highlights the imperative of incorporating social vulnerability considerations into disaster risk reduction policies. However, there remains a crucial need to acknowledge the potential utility of multi-hazard approaches, especially considering events like heatwaves and droughts, which can amplify the impacts of wildfires.

7. Conclusions

The findings of this review underscore the critical importance of addressing multi-hazard risks, especially in depopulated communities, as a challenging but critical task. Adopting a multi-hazard approach is crucial for developing a comprehensive understanding of the overall situation within a region. Analyzing the interactions among heatwaves, droughts, and wildfires allows for a more thorough assessment of the combined threat and its potential impacts on both communities and ecosystems.

The adverse effects of these events range from thermal stress and water scarcity to compromised air and soil quality. These events threaten human health, biodiversity, and the economy and undermine rural areas' cultural heritage and social fabric. Rural communities undergoing depopulation face heightened vulnerability, reaching a critical point that endangers their continuity and cultural identity. The movement of the population out of these areas significantly affects the cultural landscape, especially the preservation of built heritage with significant cultural, historical, and architectural value. The preservation of built heritage and the social integration of remaining residents are paramount concerns in these areas, requiring holistic approaches to address resource scarcity, economic decline, and social isolation, making them highly susceptible to external hazards.

Understanding the complex relationships between these hazards is essential, given their potential to act as risk amplifiers. Climate change will likely aggravate these interactions in the future, underscoring the urgency for effective mitigation and adaptation strategies. Hence, understanding the intricate interactions between these hazards facilitates better resource allocation for preparedness, response, and recovery, positively influencing community resilience.

Ultimately, this literature review serves as a foundational exploration and highlights the urgent need for further research and the development of targeted strategies to address the broad spectrum of challenges faced by vulnerable rural communities in the context of increasing climate hazards.

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